Impact of Dreissenid Mussels and Round Goby on the Benthic Macroinvertebrate Community and Ecological State of Lake Simcoe

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Lake Simcoe Region conservation authority

UNIVERSITY OF WATERLOO

LSRCA Lake Science Program

- LSRCA: one of 36 watershed conservation authorities in Ontario

- Restoration / protection of environmental health of L. Simcoe & watershed

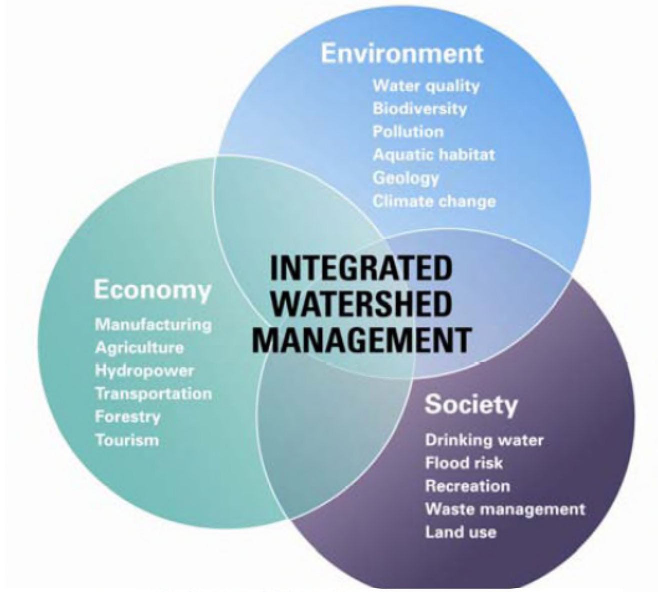
- One focus: use science to answer questions / concerns of watershed residents, understand ecosystem to assess / adapt to change

- Lake science program started May 2008 to fill data gap in Lake Simcoe nearshore zone

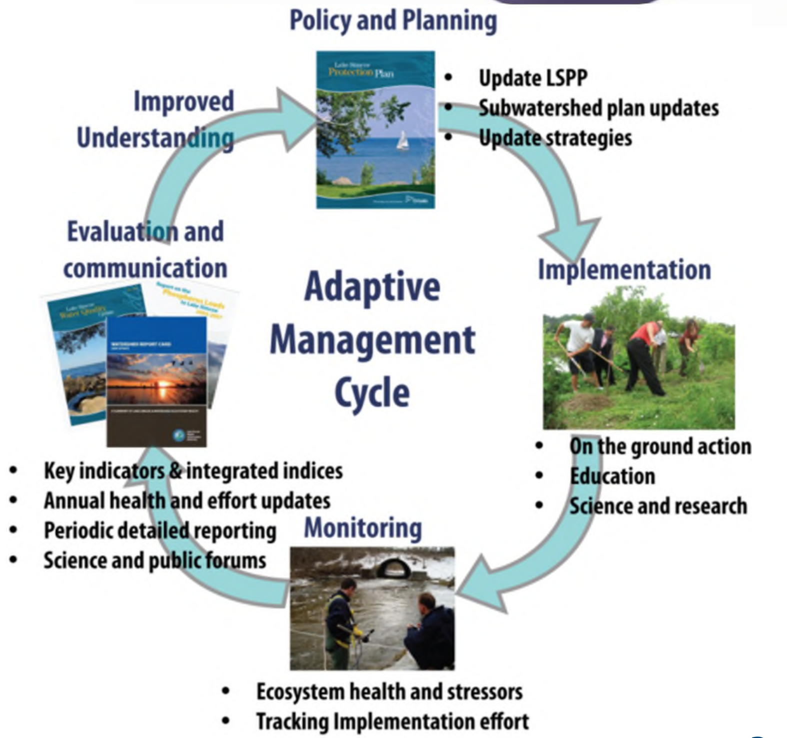
- Monitoring to track overall trends and direction of environmental change
  - water chemistry (phosphorus, etc.)
  - sediment chemistry (phosphorus)
  - physical variables (temp., pH, DO, salinity, suspended solids)
  - biological indicators (aquatic plants, algae, benthic inverts)

Scientific data needed for:

- Identify environmental problems
- Determine cause
- Put problem in context
- Set goals for recovery / restoration
- Generate solutions / strategies
- Advise lake managers / policy makers
- Evaluate recovery efforts and targets



[Integrated and adaptive watershed management]()



Lake Simcoe

- 60 km (37 miles) north of Toronto
- Watershed: 3,307 km^2 (1300 sq. mi)
- Lake: 722 km^2 (280 sq. mi)
- Z_{max}: 42 m (mean = 15 m)

- 400,000 residents (+50,000 seasonal)
- $200 million recreational fishery (~1 million angler hours, 80% in winter)
- "Small version of Great Lakes" (L. Champlain, Finger Lakes, etc.)

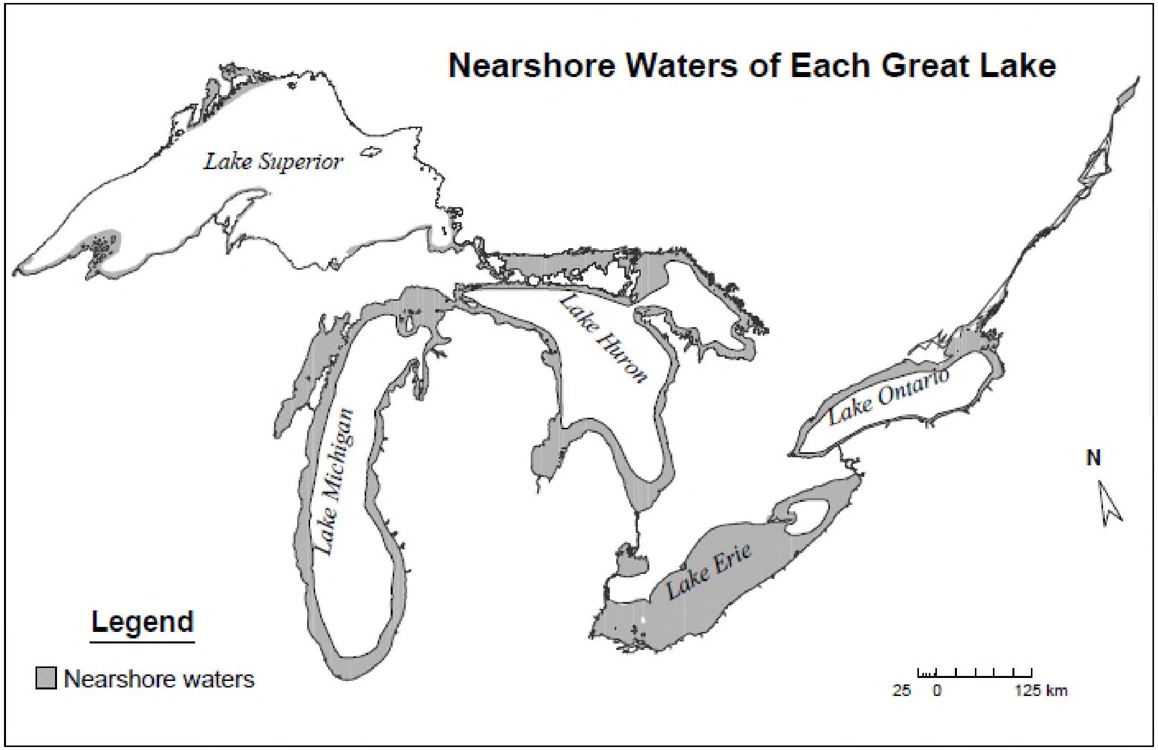
Map: Wilson 2008

Nearshore Zone

- Warmwater fish habitat
  - >10-15°C

- 15 – 20 m depth
  - size varies with lake
  - **Lake Simcoe ~67% of area**

- Ecologically important!
  - 90% of species
  - but often ignored ☹



Map: Edsall and Charlton 1997. SOLEC 1996

- Intense interest by lake users (visible + recreation)

- Significant environmental changes (nutrients, invasive spp, development)

Lake Simcoe: 5 environmental stressors

- **Watershed development / urbanization**
  - Altered run-off, shoreline hardening, fertilizers / chemicals
- **Phosphorus loading:**
  - Reduce to 44 tonnes (currently ~76 t, 1980s ~100 t)
  - Water column TP = 10 µg/L (currently 15-21 µg/L, 1980s 20-30 µg/L)
- **Deepwater Oxygen:**
  - Restore coldwater fish habitat: hypolimnetic O_2 >5 mg/L (target = 7mg/L)
  - Sustainable populations of lake trout, lake whitefish, lake herring
- **Climate change:** Changes to water supply (precipitation), quality and quantity
- **Invasive species:** Changing biological communities / loss of native species

Benthic macroinvertebrate community

- Animals living on / in the lake bottom
- Species composition varies with substrate / habitat availability
- Molluscs, worms, crayfish, scuds, sponges, insect larvae, etc.
- Some taxa very sensitive to environmental conditions
- Important role in nutrient / energy cycling, food source for fish

Photo: R. Bolton, LSRCA; USGS

Dreissenid Mussels

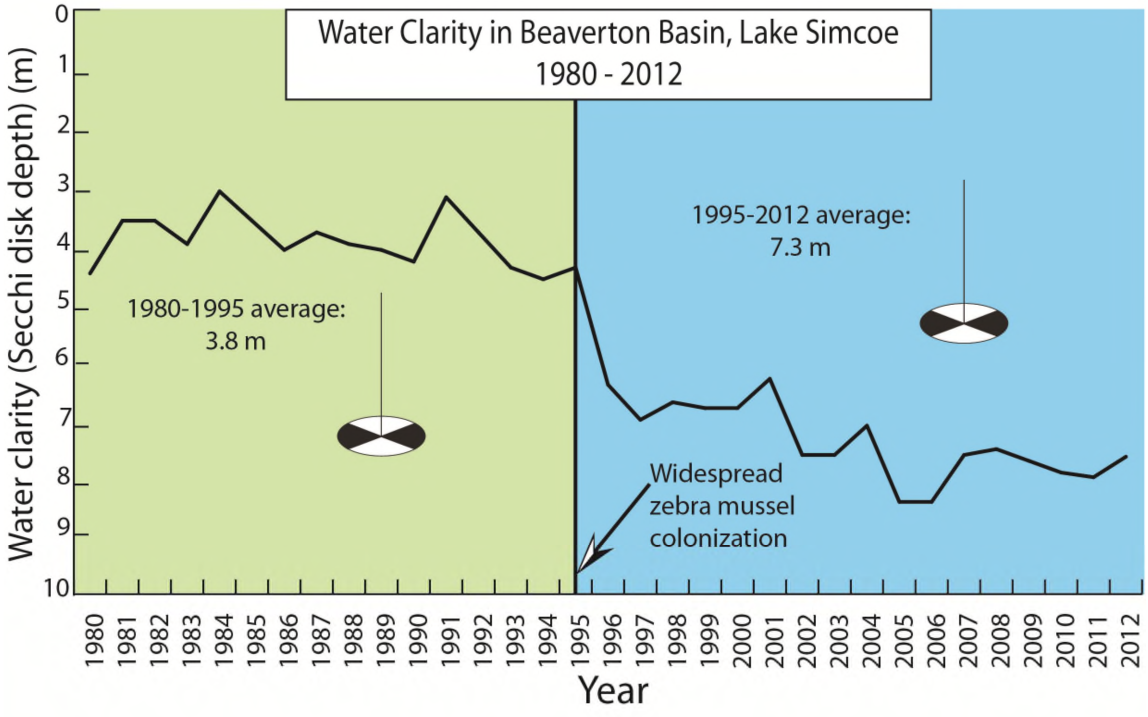
Zebra mussel (*Dreissena polymorpha*)
- Great Lakes ~1986
- Lake Simcoe 1991-2, established by 1995

Quagga mussel (*Dreissena rostriformis bugensis*)
- Great Lakes ~1989
- Established in Lake Simcoe ~2004

- Colossal ecological changes (esp. foodwebs)
- Filter Lake Simcoe ~5 days
- Offshore nutrients → nearshore
  - Nearshore Shunt (Hecky et al. 2004 CJFAS)
- Habitat changes:
  - more detritus / P deposition / refugia in shell debris

Photos: USGS

Impact on water clarity



Data: MOE 2010 (1980-2007); LSRCA (2008-2012)

More clarity = More plants!

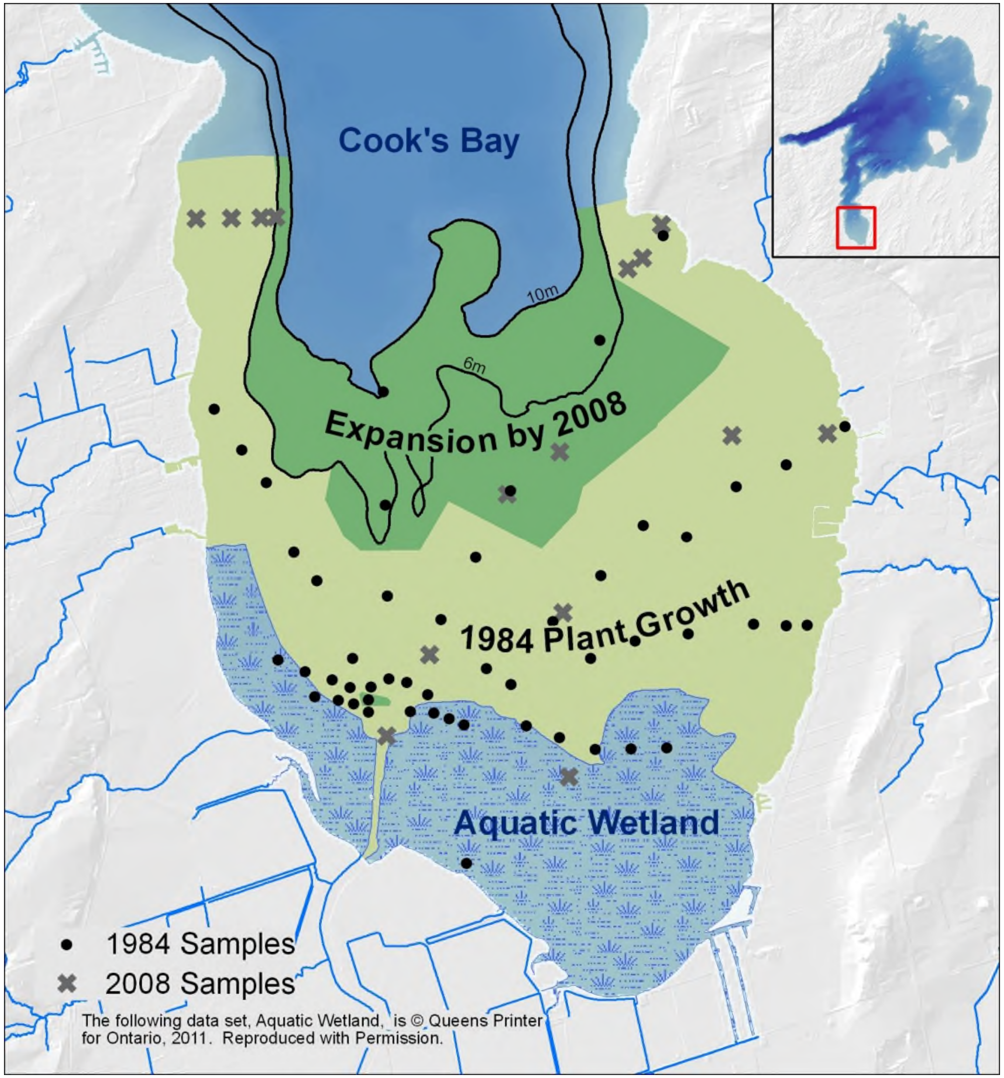
1984-1987:

- Max. depth: 6.0 m
- Mean wet wt: 1.2 kg/m^2

Deeper + 3X more plants

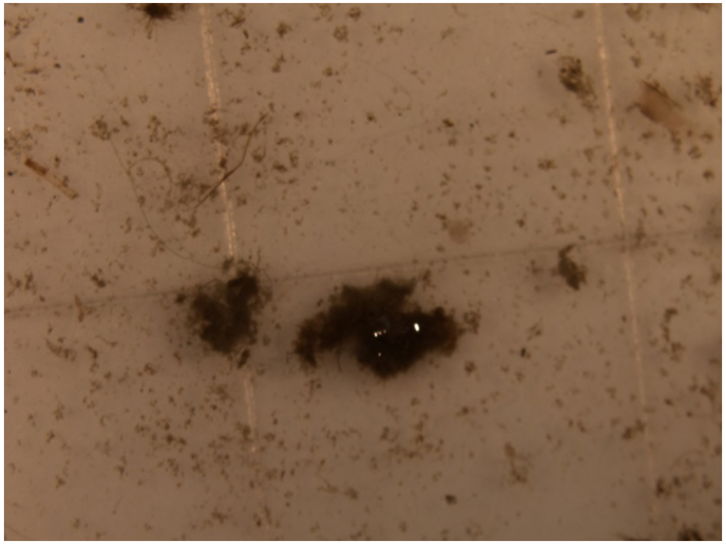
2008 - 2011:

- Max. depth: 10.5 m
- Mean wet wt: 3.1 kg/m^2

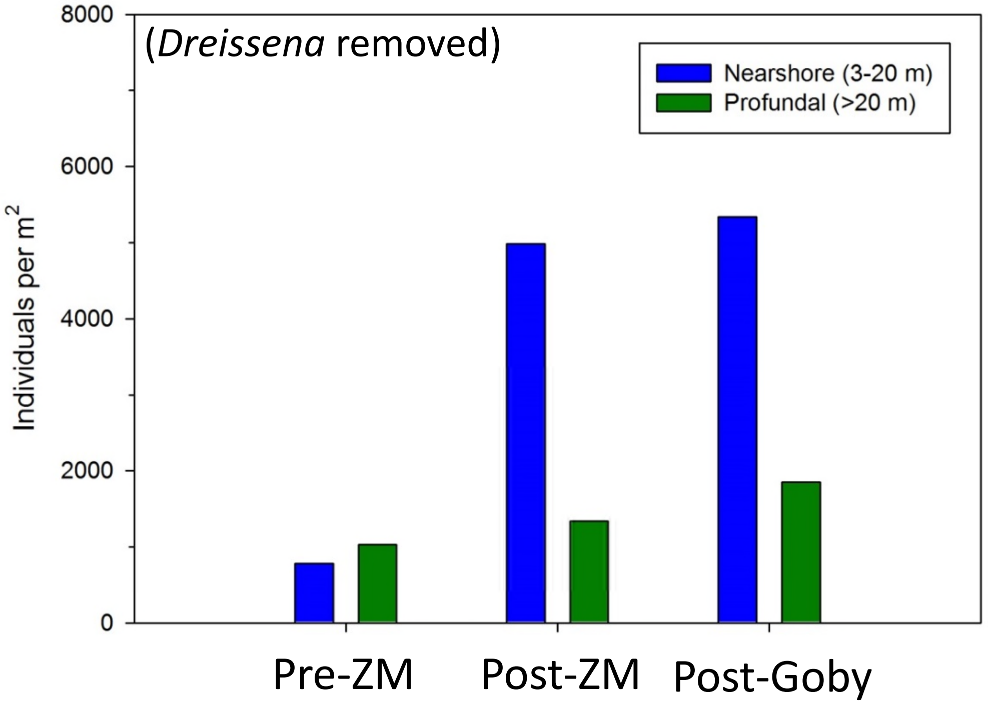


Ginn 2011. JGLR

More nearshore P = increased density



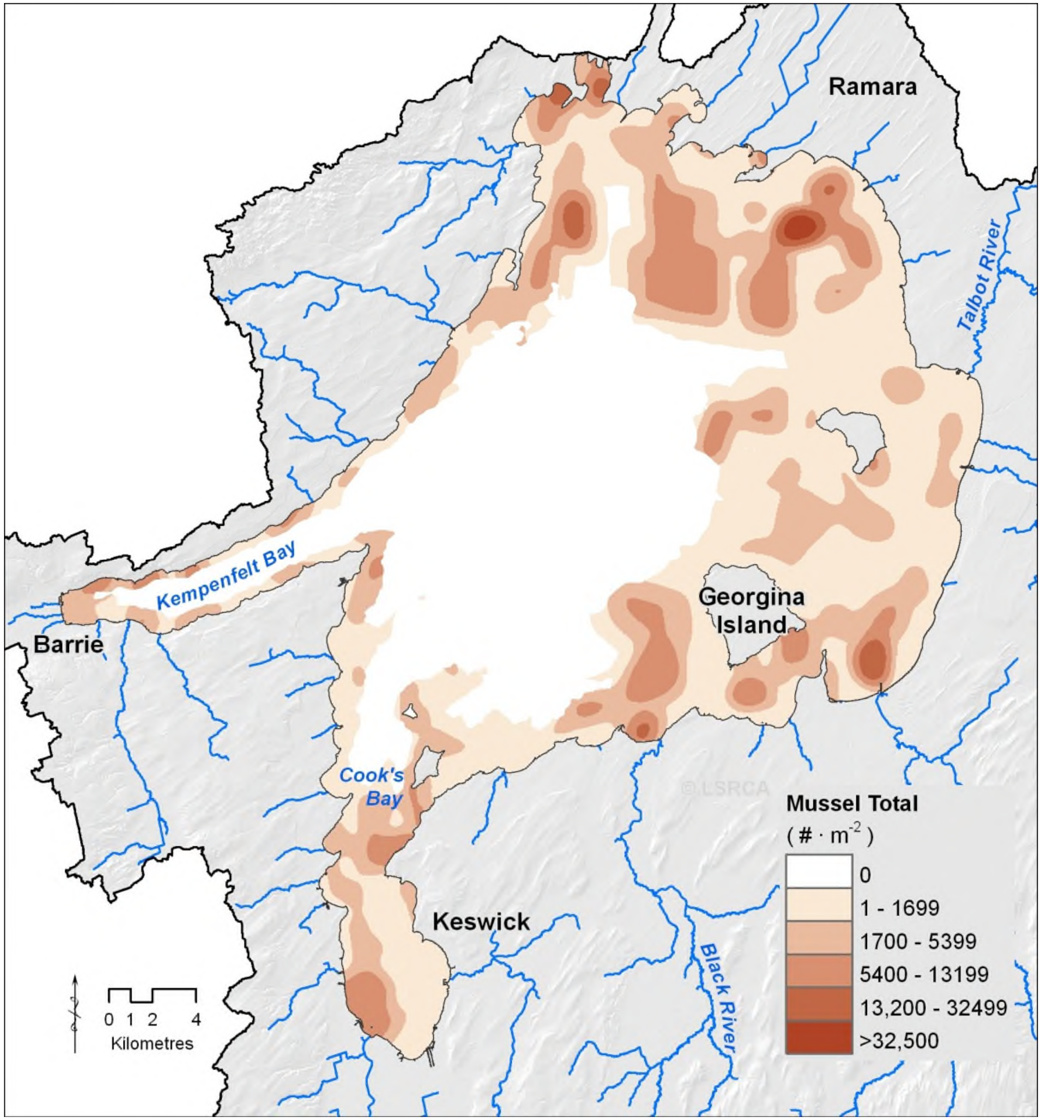
"biodeposits"



- **<u>HUGE</u>** increases to benthic populations and biodiversity
- Nearshore fish: 2.5-3X increase post-ZM

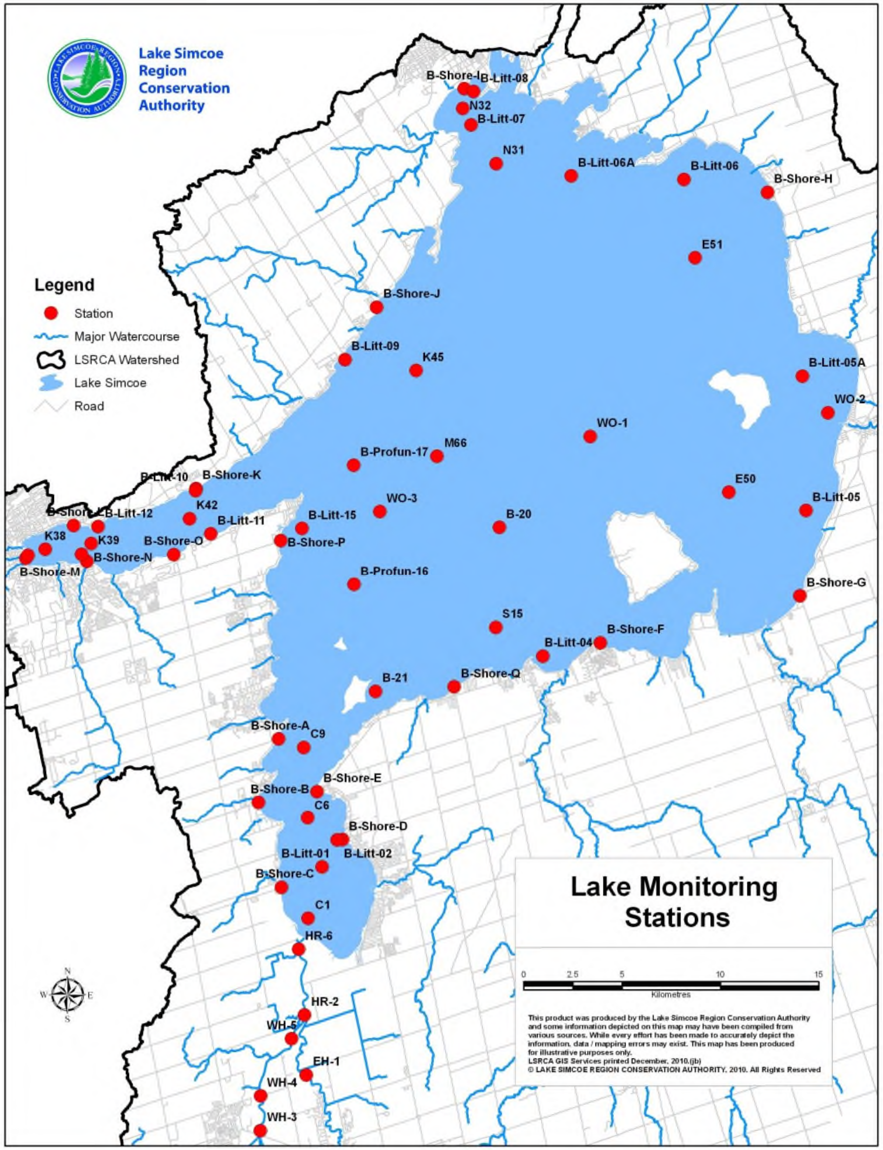
Dreissenid mapping (2009)

- 747 sites (43,952 mussels)
- Mean biomass: 20.1 g·m^{-2}
  - ~4015 individuals /m^2
  - 75% ZM : 25% QM
- Limited to < 20 m
  - except Kempenfelt Bay (~31 m)
- Quaggas increasing
  - esp. 10-20 m depths

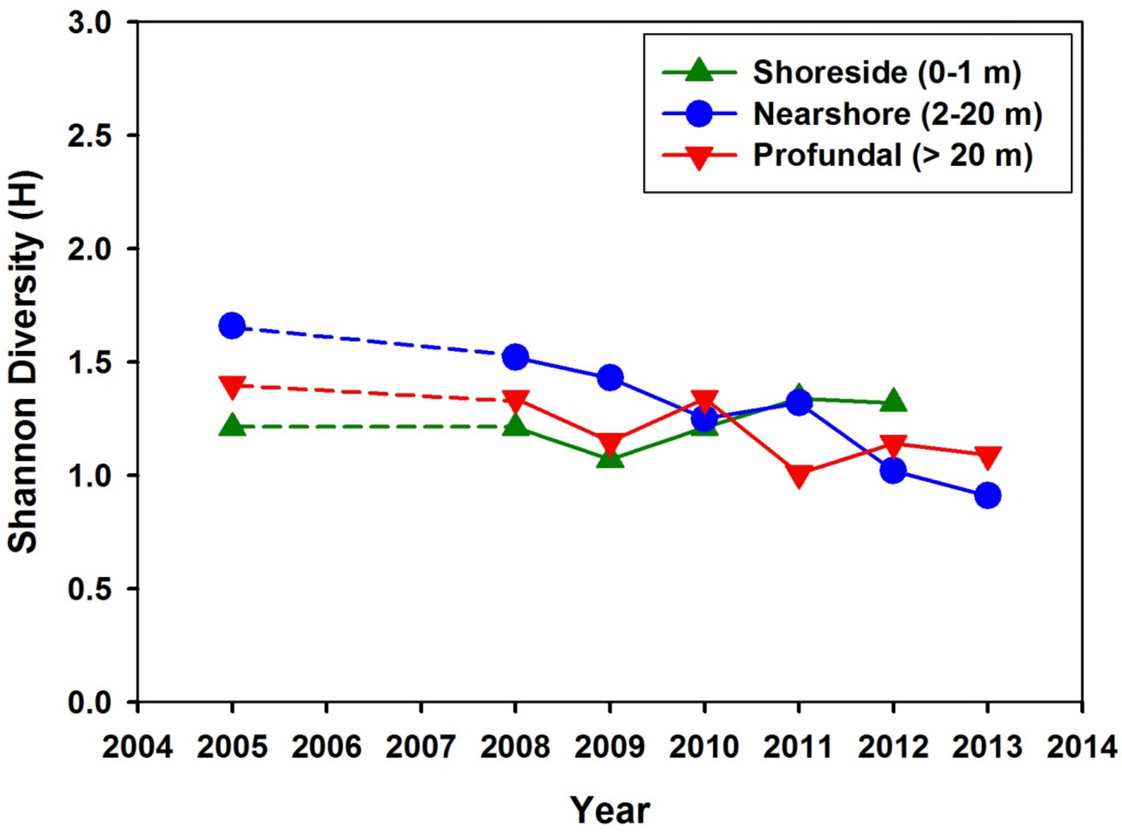


Methods

- Expanded on Kilgour et al. (2007. J. Great Lakes Res.)
- Sampled annually (October)
- ~49 sites, stratified by depth:
- **Shoreside**: 0-1 m (17 sites)
- **Nearshore / Littoral**: 2-20 m (20 sites)
- **Offshore / Profundal**: >20 m (12 sites)

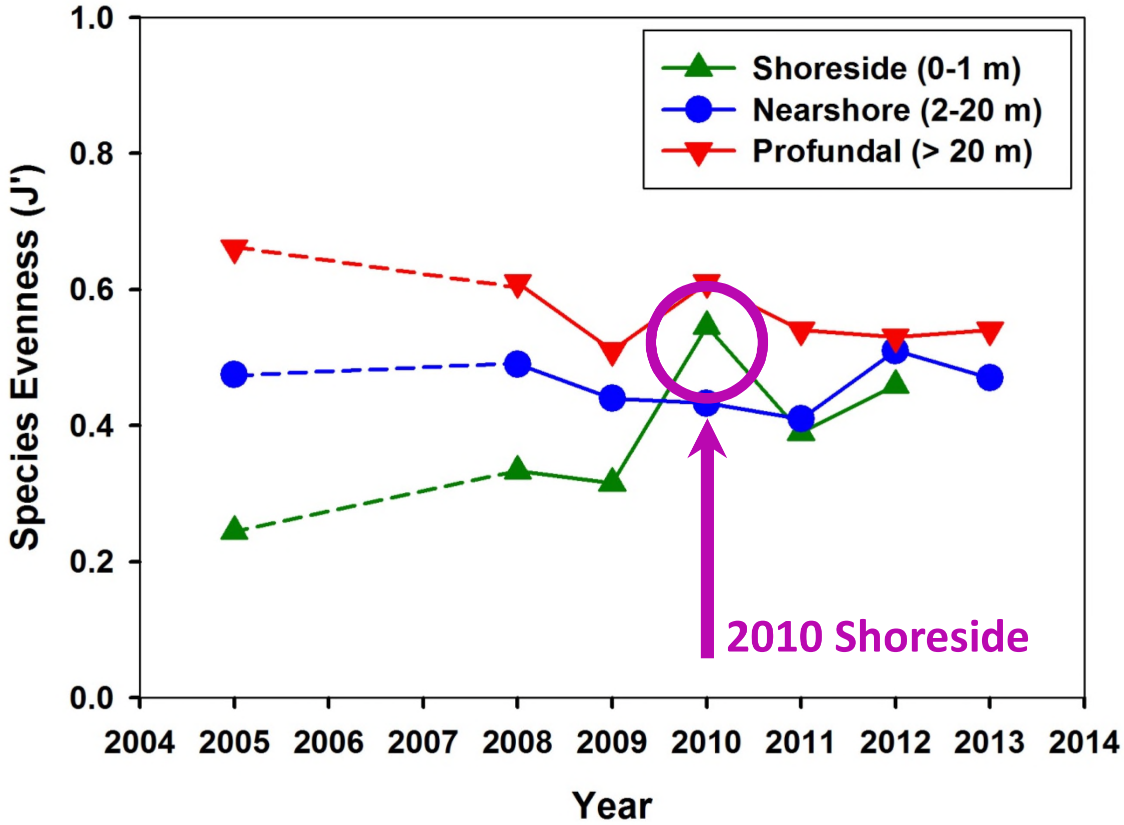


Trends in Taxa Diversity



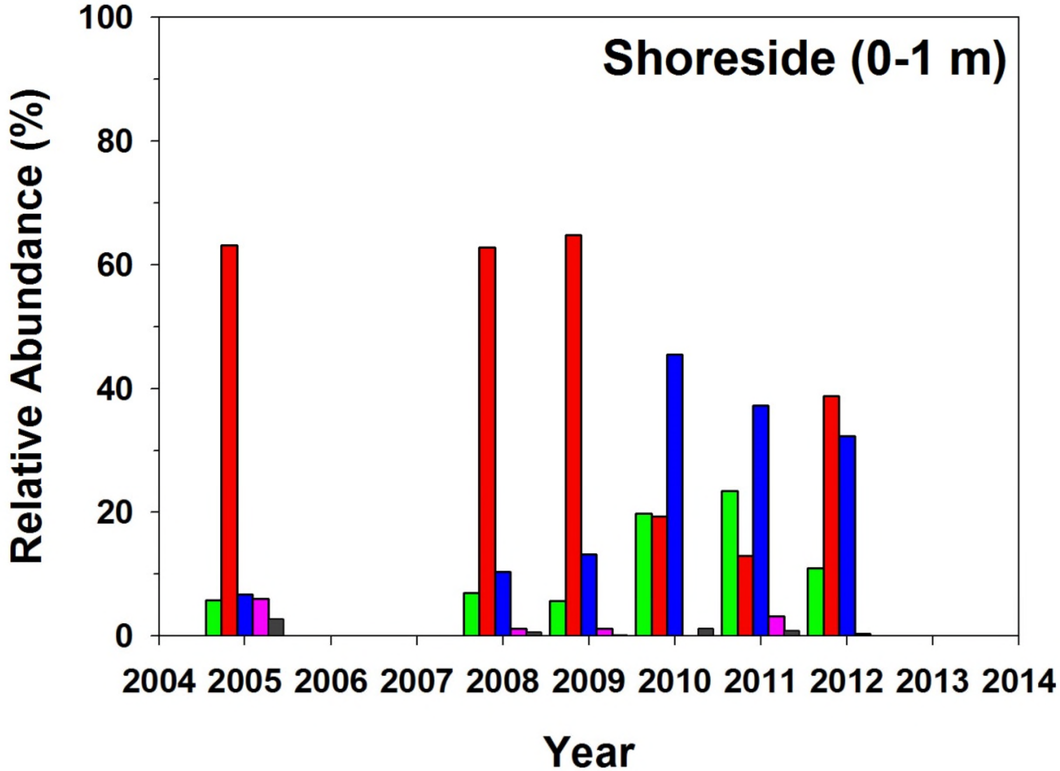
- relatively stable
- nearshore: highest until 2011
  - typical of shallow lakes
  - declining since 2011
- shoreside = lowest
  - most variable conditions

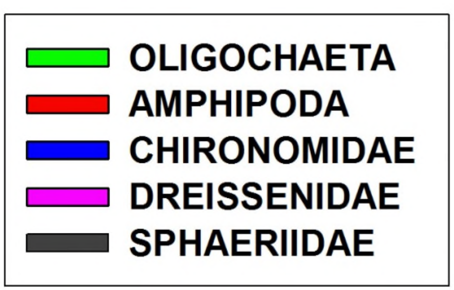
Trends in Evenness



- Also relatively stable
- 2010 shoreside more even

Shoreside (0 – 1 m depth)

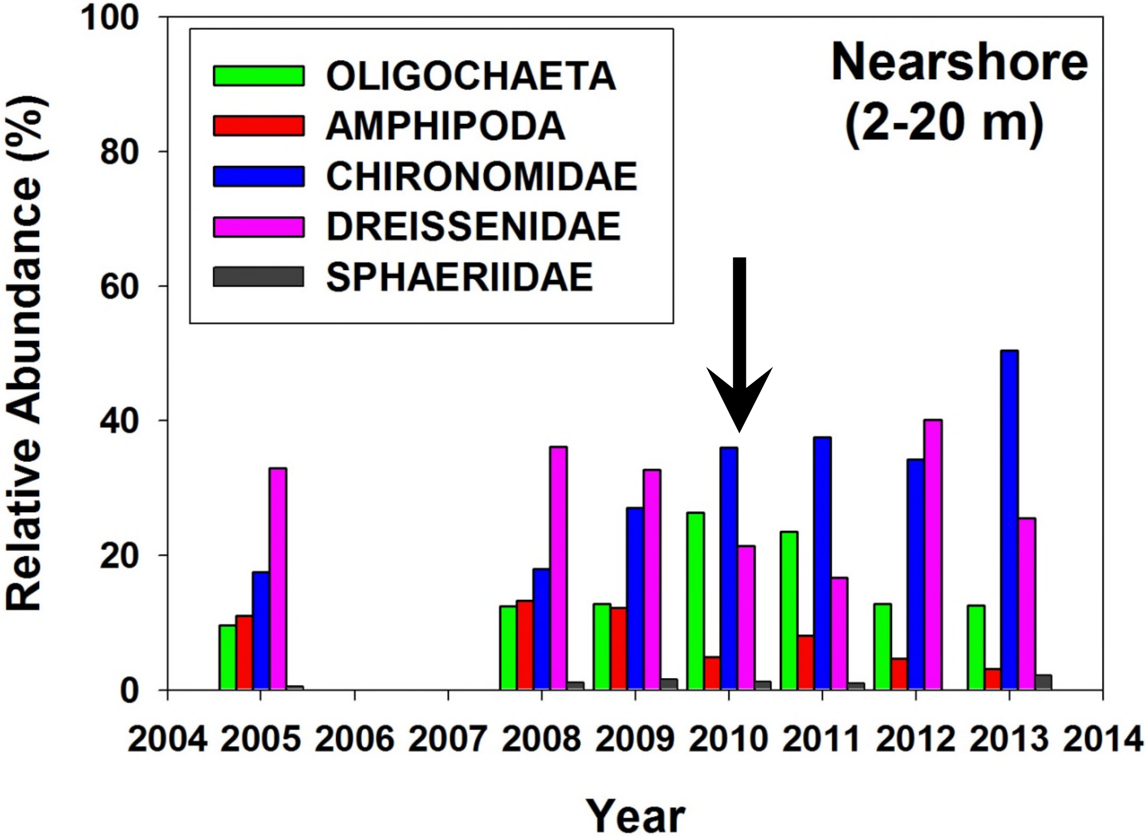




- Very variable conditions
  - Temperature, nutrients, physical forces
- Few dreissenids
  - wave action / ice scour
- Amphipod-dominated (until 2010)
  - Round Goby
- 2012: amphipod “resurgence”
- ***BUT***: is re-bound invasive spp?
  - *Echinogammarus ischnus*
  - L. Ontario / L. Erie

2005 data: Kilgour et al. 2007. JGLR; Photo: USGS

Nearshore (2 – 20 m depth)

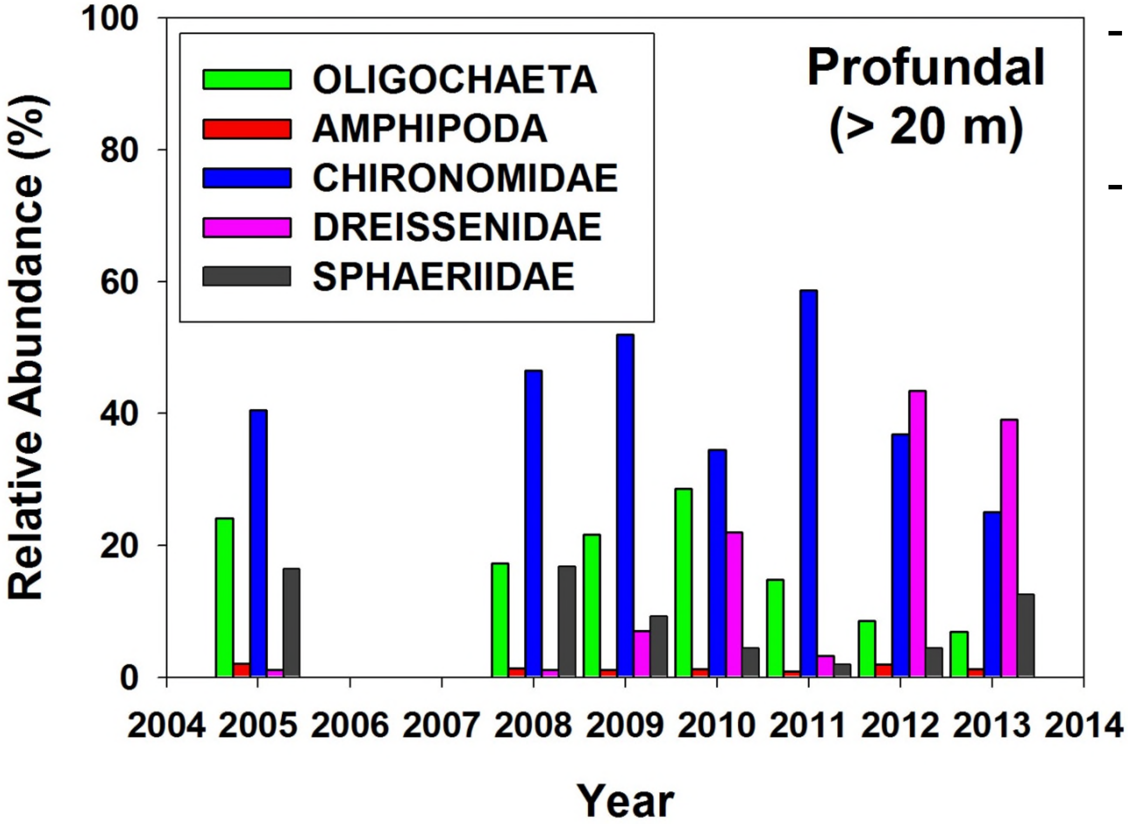


- 2005-2009: Zebra mussels
- 2010-11: ZM decline!
  - Round Goby

- 2012: mussel "resurgence"
  - ***BUT***: Quagga mussels

2005 data: Kilgour et al. 2007. JGLR; Photo: USGS

Profundal (> 20 m depth)



- Chironomids dominant
- Increasing dreissenids (Quaggas)

2005 data: Kilgour et al. 2007. JGLR

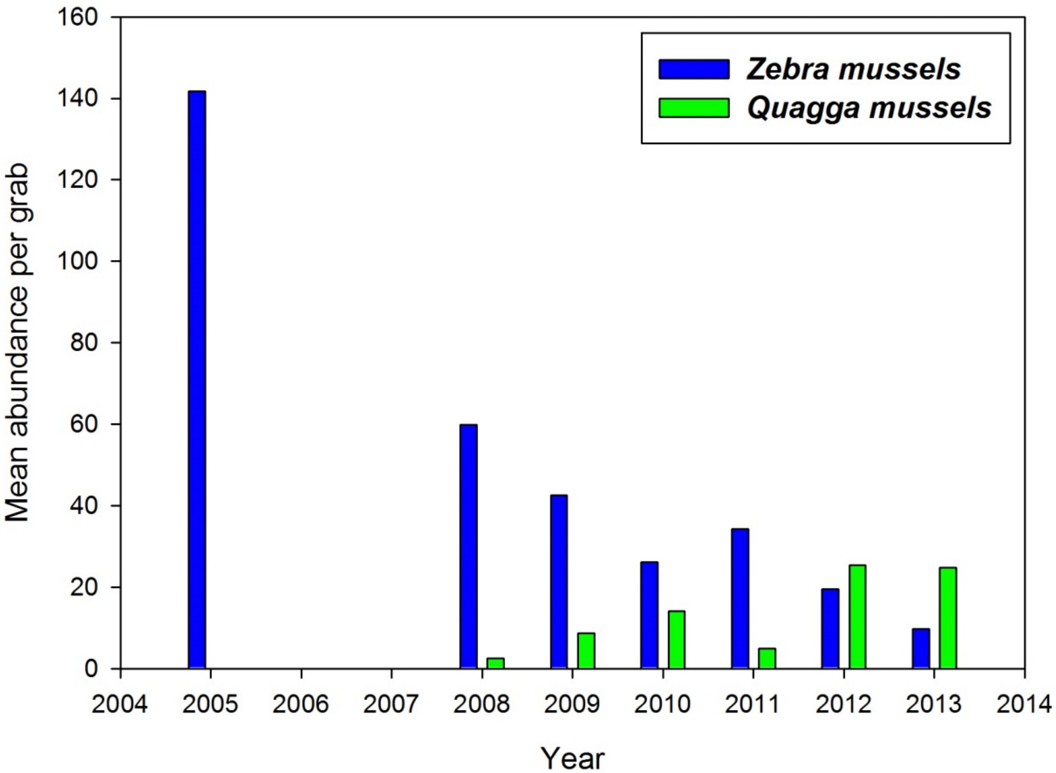
Change in Dreissenid Composition

- Decline in zebra mussels

- ZM ~67% of goby stomach content
  (Trumpickas et al. 2012 IAGLR)

- Increase in Quaggas
  - Exploit new habitat space
  - Better cool water survival
  - Longer growing season
  - Attach to less ideal substrates

- Same trend recorded in L. Ontario, L. Erie, and L. Michigan



Consequences of change?

- Dreissenids = ecosystem "engineers"

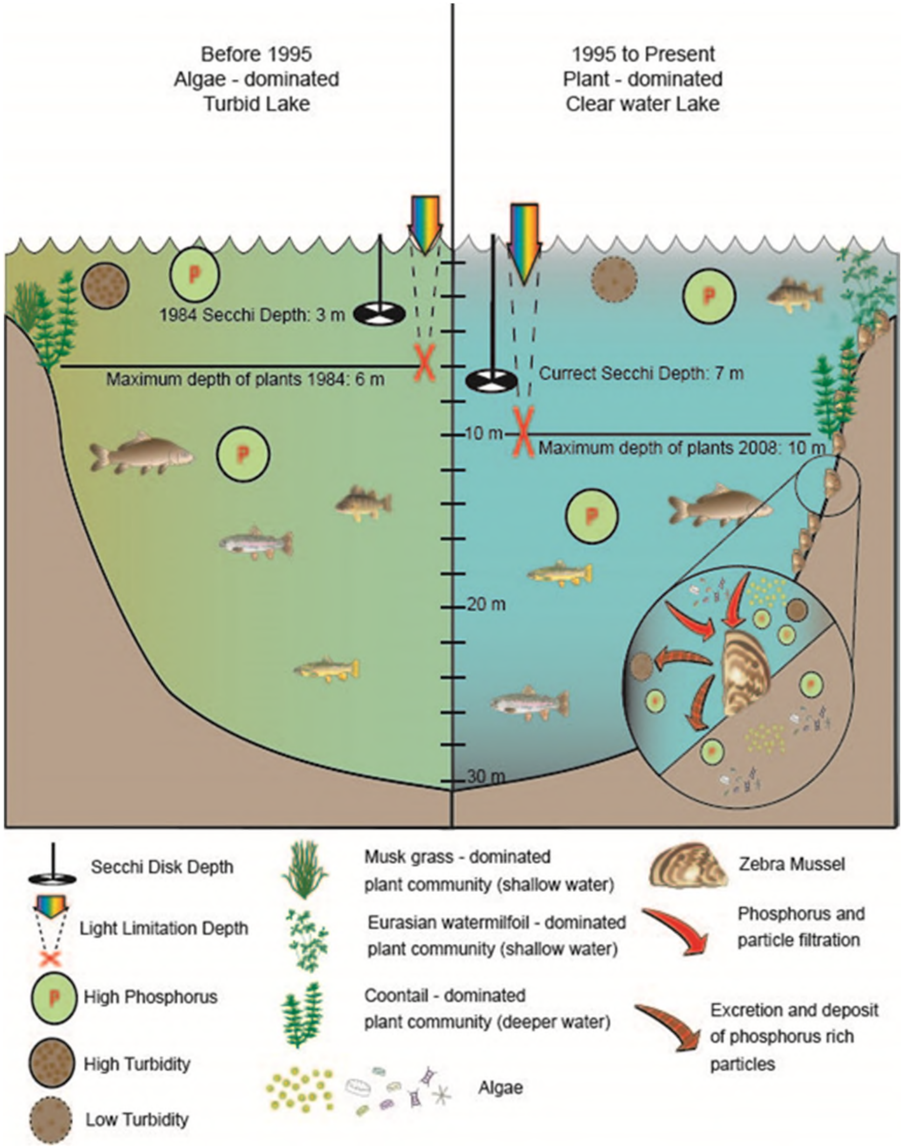
- ZM invasion = increased water clarity

What happens with ZM decline?

- Are quaggas as efficient at filtering?

- Phosphorus still deposited on bottom?

- P re-suspended? Exported to offshore?



Future Scenarios?

- L. Ontario / L. Michigan: clear water
  - P deposition maintained by QM?

- L. Erie: turbid, algal, cyanobacteria
  - More SRP relative to TP? (Scavia et al. 2014 JGLR)
  - Flux from benthos / sediments? (Pennuto et al. 2014 JGLR)
  - Climate? (Michalek et al. 2013 PNAS)
    - 2011: wet spring, hot summer, sediment re-suspension, cyanobacterial bloom

- Where on this gradient is Lake Simcoe?
  - Data and monitoring are needed to answer these questions!

Photo: NOAA / NASA

Acknowledgements

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  - Lake Simcoe Conservation Foundation
  - University of Waterloo

R/V Ouentironk

Conclusions:

- (mostly) stable trends in benthic diversity and evenness

- Big changes from dreissenid and round goby invasion

- Zebra mussel population declining rapidly in Lake Simcoe
  - Goby Predation!
  - habitat now occupied by quagga mussels

- What’s next?
  - Are Quaggas as efficient at filtering algae / moving P?
  - P re-suspension or more SRP? L. Erie
  - Continued benthification? L. Ontario / L. Michigan

Photo: USGS